

On The History of Biological Membranes

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May 6, 1974

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Cell membranes are an integral part of all living organisms. Even though the membranes of each cell type are unique, all share striking similarities in composition, morphology, chemistry, and biophysical characteristics.

The most obvious purpose of the biomembrane is compartmentation. They sequester the living, metabolizing protoplasm from the ~~external~~ ^{membrane} environment. When we degrade the cell wall of an erythrocyte, for example, or even poke microscopic holes in it, the cell material pours out, ~~becoming as inert as the solution.~~ ^{inaccurate} Compartmentation is only one of many different and elegant functions which can be ascribed to membranes, ~~but~~ ^{yet} clearly illustrates its vital role in all living cells.

The history of the membrane as a function of life itself is one of interest. * Where did the membrane begin as compared to the beginning of life ~~itself~~? Has the role of the membrane changed during evolution? Most important, why are all membranes so similar, and why are they a "sine qua non" in the biological machinery of life?

The three theories of membrane biogenesis which will be discussed are convergent evolution, environmental coincidence, and prebiological determination.

~~Convergent evolution is an evolutionary process in which parallel or similar biological~~

* Was the membrane the result or a motive in biological ~~question~~ ^{development}? Did some stage in the ~~prebiological~~ - chemical evolution ^{pre life} process depend on a basic membrane or did the membrane evolve ^{within} living systems as a selection phenomenon.

The implications of this question are of direct biological interest. Specifically they ~~shed~~ ^{doubtful} question the ~~ability~~ ^{ability} to speak of cell organelles as regards to their function in the cell.

The origin of sub-cellular components ~~xxxxxxx~~ in general is a problem of speculative interest. In some cases, we can find organelles which serve similar purposes in different organisms, yet which have few, if any, common precursors. An example is the photosynthetic apparatus. While eucaryotes have complicated chloroplasts which trap light, the systems in photosynthetic bacteria also use light to initiate energy processes using different pigments, different enzymes, and a different overall morphological setup. This is an example of convergent evolution on a subcellular level. Different organisms developed similar (functionally speaking) organelles by different means in response to similar environmental conditions. Convergent evolution is seen more easily on the macrobiological level. Although a shark and a dolphin appear similar, they are from different evolutionary branches. However, in adapting to the same environment they have developed separately similar morphological characteristics.

Biological membranes, it is argued, are the result of convergent evolution. Different organisms at different times have developed membranes of the general type ^{as} we know them, because it was and remains the best (or only) system for the functions it is called on to perform. The similarity arises from parallel function and not a common precursor. The differences that exist between membranes show their separate development.

Let us assume for a moment that the lipid-protein membrane was arrived at separately by different organisms, and, being the best answer to the existing functional problems, was developed convergently, from different beginnings. The immediate question which is brought to mind, is, if this membranal development was so crucial to the continuation of life at different points in evolutionary history, ~~and~~ that no trace remains of those organisms who did not develop such a membrane, why were the ancestors able to survive without these membranes? One can answer that they also had a membrane, but of a more primitive nature. If so, ~~xxx~~ then what was wrong with it?

Another pertinent problem is that of membrane biogenesis. Though a cell is capable of synthesizing enzymes from amino acids, and building polymers of sugars, beginning with a single glucose ~~xxxxx~~ molecule, there is no known example of a case where a cell can create a membrane. While cells do synthesize specific membranal proteins and lipids, which then undergo incorporation into the membrane, the result is the growth of existing membranes. When membrane-bound organelles, such as glyoxysomes, are created in the cell, they are released as bubbles from the Golgi apparatus, itself a folded membrane. Why must cells use membrane-bound organelles to create others of the same? The answer is that they lack the ability to

organize synthesized lipids and proteins into a membrane structure, but must incorporate them into an already-existing one. Why is this? Perhaps the cells at one time were able to synthesize membranes "de novo", but lack of this need over the course of time led to loss of this genetic capacity. It is unreasonable, however, that this ability should not be present in at least a few cases. So far, none such have been found. Alternatively, it is possible that cells are able to synthesize membranes de novo, ~~xxxx~~ but are no longer ~~xxxxxxx~~ engaged in this process. If we were to remove their cell membrane, they would die before given a chance to demonstrate their synthetic abilities. On the other hand, if this ability still exists, why must cells resort to intricate membrane systems such as the Golgi to release membrane-bound organelles?

The most reasonable answer, is that the ability to synthesize closed lipid-protein membranes from scratch, is a capacity which living organisms never had, and still do not.

It is believed that certain biological phenomena are the result of external effects, or coincidences, which are the result of sudden environmental factors as opposed to genetic mutations over long periods of time, which is the molecular basis for evolution. For example, it is thought that the mitochondria originated as separate organisms, who entered other organisms and lived symbiotically in the host cell. This parasitic intervention led to great changes in energy metabolism, for example. With time, the mitochondria and the eucaryotic cell have become completely dependent on one another and the reverse process of separation would lead to the death of both the organelle and the cell itself.

The membrane could be such a historical coincidence. Perhaps at some point in the early development a lipid layer, then two lipid layers adsorbed to the metabolizing cell. The cell then began to modify the lipid layer genetically, and at the same time accustom itself to the ensuing physiological changes.

This view is subject to many of the arguments previously levelled against evolutionary development. Why should lipids have adsorbed to all cells? Could they not, in the course of time, have desorbed as well? How were the cells able to develop without membranes previously? If an earlier method of compartmentation was present, where are its traces?

The direct involvement of membranes in the course of biogenesis is plausible for a number of reasons. Firstly, assuming the hypotheses of Oparin with regards to reducing atmosphere and an organic soup, ~~there~~ there is no reason that a lipid layer should not have covered the primeval seas and lagoons. Although long chain hydrocarbons and water are not miscible, when such mixtures are shaken, closed microscopic sacs with a lipid bilayer (similar in many ways to biological membranes) are created, enclosing a volume of water. The existence of such tiny vesicles created a separation of the internal solution from the external. Different concentrations of solutes and different molecules and oligomers evolved slowly within the vesicles. Life may have arisen out of this primitive morphological system.

If the origin of the membrane lies in biogenesis itself, the structure and characteristics of the cell have always been strongly interrelated. Therefore, the reason that the lipid-protein membrane is the best is because the cell has adapted to it much the same as the membrane metamorphosed to suit cell function.

Two cell characteristics are of interest here. Firstly, cells are rich in potassium ion and poor in sodium ion. They engage in an active^{*} process of maintaining an ionic imbalance ~~wt~~ with the extraneous solution. Why is this? It can be argued that optimum growth of the cell requires high potassium concentration, so the cell expends energy towards this end. It could also be, however, that during biogenesis, the conditions in the organic soup were those of high potassium and low sodium concentration, and the early cell developed under these conditions. When conditions changed, the cell was forced to find a process to maintain the ionic status quo. Thus, the membrane developed intricate lipoprotein pumping units which are active to this day.

** energy consuming*

The second point of interest is internal cellular water concentrations. Bacteria, for example, may contain up to 90% water (by weight). Why this great preponderance of water? Water, it can be argued, is the universal solvent. Any organic chemist knows that reactions in solvent occur much faster than mixing of two reactive powders. On the other hand, since when has rate been a factor in biological development? If the development of life itself took over a billion years, what difference should the rate of metabolism have on the organization of a particular organism? If all the metabolic processes of a human were twice as ^{slow} long, we should ~~lx~~ live twice as long. However, it could be that at an early stage, the primitive cells had no control over water level. Although lipid membranes are impermeable to many chemicals, they have no control over water. The first organisms, then, were prey to the Donnan equilibrium. The water concentration was determined by osmosis and electric potential. These primitive cells had no alternative but to build their structure and metabolism in dilute aqueous medium, and thus it remained.* In later stages, bacteria and plant cells developed thick, porous cell walls, to guard against osmotic changes which could explode the cell.

To discuss cellular components, then, in terms of structure and function, is not accurate, ~~xxxxxx~~ To argue that the membrane fulfills many necessary functions of the living cell is inaccurate; it can also be argued that many of the functions of the cell itself are dependent on membrane structure.

We cannot accept the biogenetic origin of the membrane without some reservations. There are a number of other theories of ~~xxxx~~ morphological development which do not take the membrane as a sine qua non. And even if we do, we are still confronted

* Thus, to say that cells require a high concentration of water in order to function, may be one of historical necessity and adaptation, rather than choice.

* Bacteria frozen in Antarctica for over 10,000 years have been ~~isolated~~ resuscitated.

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with the following problem. If living organisms developed within a lipid-based membrane whose lipid source was extraneous, how and why did they learn to synthesize new lipids internally and incorporate them into the membrane? The bacteria *Mycoplasma Laidlawii* can both synthesize membrane lipids from simple precursors and incorporate lipids supplied extraneously direct into its cell membrane. His ancestor must have learned to supplement the membrane he was given. But since these 'spontaneous' membranes had no connection with the genetic apparatus, how ~~id~~ did the cell come to synthesize the same lipid-protein combination that existed in the membrane?

He probably did not. ~~xxxxxxx~~ Membranes composed of diverse mixtures of lipids are just as feasible thermodynamically as those of one or two species; sometimes moreso. But, the transition from membranes whose components and perhaps structure were determined by the extraneous organic soup solution, to the membrane genetically determined may have been a large transition. So large, in fact, that perhaps the membranes we see today are more due to evolutionary development than biogenesis. On the other hand, without a protomembrane, evolution would have had nothing to build onto.